CHEMICAL AND MINERALOGICAL CHARACTERIZATION OF A HEMATITE-BEARING RIDGE ON MAUNA KEA, HAWAII: A POTENTIAL MINERALOGICAL PROCESS ANALOG FOR THE MOUNT SHARP HEMATITE RIDGE. T. G. Graff[1], R. V. Morris[2], D. W. Ming[2], J. C. Hamilton[3,4], M. Adams[3], A. A. Fraeman[5], R. E. Arvidson[5], J. G. Catalano[5], and S. A. Mertzman[6], [1]Jacobs, NASA JSC, Houston, TX 77058 (*trevor.g.graff@nasa.gov*), [2]NASA JSC, ARES, Houston, TX, [3]University of Hawaii, Hilo, HI, [4]Pacific International Space Center for Exploration Systems, Hilo, HI, [5]Washington University in St. Louis, St. Louis, MO, and [6]Franklin and Marshall College, Lancaster, PA.

Introduction: The Mars Science Laboratory (MSL) rover Curiosity landed in Gale Crater in August 2012 and is currently roving towards the layered central mound known as Mount Sharp [1]. Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) hyperspectral data indicate Mount Sharp contains an ~5 km stratigraphic sequence including Fe-Mg smectites, hematite, and hydrated sulfates in the lower layers separated by an unconformity from the overlying anhydrous strata [1,2,3].

Hematite was initially detected in CRISM data to occur in the lower sulfate layers on the north side of the mound [2]. [3] further mapped a distinct hematite detection occurring as part of a ~200 m wide ridge that extends ~6.5 km NE-SW, approximately parallel with the base of Mount Sharp. It is likely a target for *in-situ* analyses by Curiosity.

We document here the occurrence of a stratum of hematite-bearing breccia that is exposed on the Puu Poliahu cinder cone near the summit of Mauna Kea volcano (Hawaii) (Fig.1). The stratum is more resistant to weathering than surrounding material, giving it the appearance of a ridge. The Mauna Kea hematite ridge is thus arguably a potential terrestrial mineralogical and process analog for the Gale Crater hematite ridge. We are acquiring a variety of chemical and mineralogical data on the Mauna Kea samples, with a focus on the chemical and mineralogical information already available or planned for the Gale hematite ridge.

Samples and Methods: We report here data for two hand samples from the hematite ridge (HW13MK001A and HW13MK029) and two hand samples from nearby subparallel strata (HW13MK025 and HW13MK032). The presence of specular hematite was obvious in the field from the grey color (hematite cement) and individual up to mm-sized individual crystals.

Size fractions (<150 μm and 500-1000 μm) were obtained by grinding and dry sieving. Major element chemistry with weight loss on ignition (LOI) and Fe-redox was obtained on bulk sample. VNIR spectra (ASD: 0.35-2.5) and XRD powder patterns (CheMin-IV: 4-50° 2θ Co) were obtained on the <150 μm size fraction of bulk sampled obtained by grinding and dry sieving.

Results: Major element chemistry (Table 1) shows that the breccia samples are highly altered compared to the average composition of unaltered Hawaiitic tephra (AUHT from [4]). The ridge samples have 28-43 wt.% Fe_2O_3T compared to 12 wt.% in AUHT. The other two samples contain high concentrations of SO_3 (~9 wt.%) consistent with acid sulfate alteration [e.g., 4].

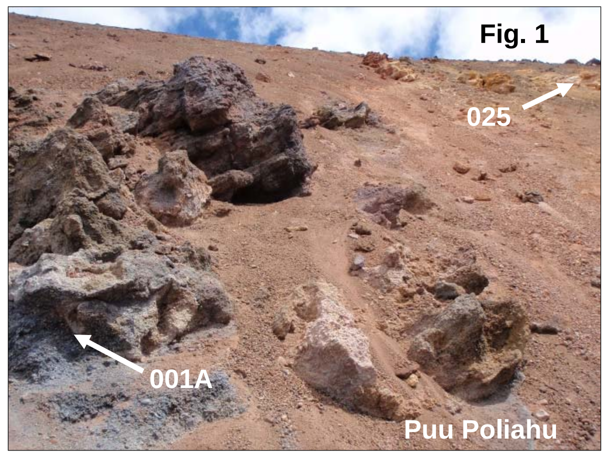


Table 1. Major element chemistry.

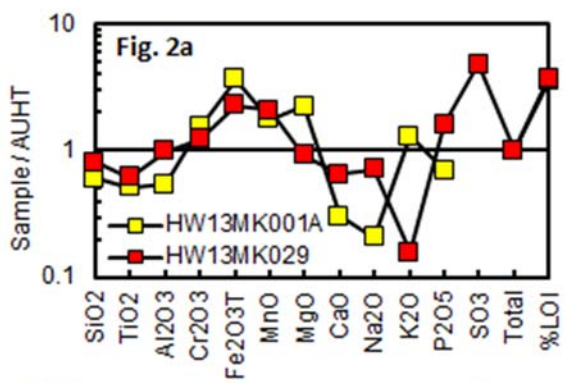
		HW13MK-			
wt.%	AUHT	001A	029	025	032
SiO_2	49.69	30.27	39.91	44.27	38.27
TiO_2	2.77	1.43	1.71	2.05	1.88
Al_2O_3	17.33	9.45	17.09	27.67	12.48
Cr_2O_3	0.003	0.005	0.004	0.005	0.005
Fe_2O_3T	12.02	43.49	27.52	4.38	25.95
MnO	0.21	0.37	0.44	0.06	0.08
MgO	3.93	8.82	3.57	1.21	1.01
CaO	6.59	2.00	4.31	3.64	3.18
Na_2O	4.33	0.89	3.09	3.87	4.30
K_2O	1.90	2.47	0.30	2.10	2.25
P_2O_5	0.85	0.59	1.37	1.40	0.79
SO_3	0.09	nd	0.45	8.86	9.88
Total	99.71	99.80	99.76	99.51	100.06
LOI	1.60	5.63	5.93	23.88	17.29
FeO	n/a	0.53	1.43	1.21	1.67
Fe_2O_3	n/a	42.84	25.97	3.46	26.78

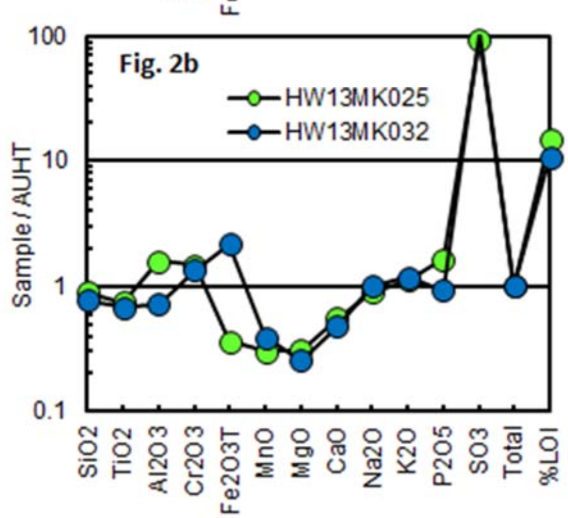
AUHT = Average Unaltered Hawaiitic Tephra

The chemical trends are shown more clearly in Figure 2 where the data are ratioed to AUHT. The XRD patterns (not shown) confirm the presence of hematite in these samples. For the SO_3-rich samples, Al_2O_3>Fe_2O_3 for HW13MK025 and vice versa for HW13MK032, suggesting (and confirmed by XRD)

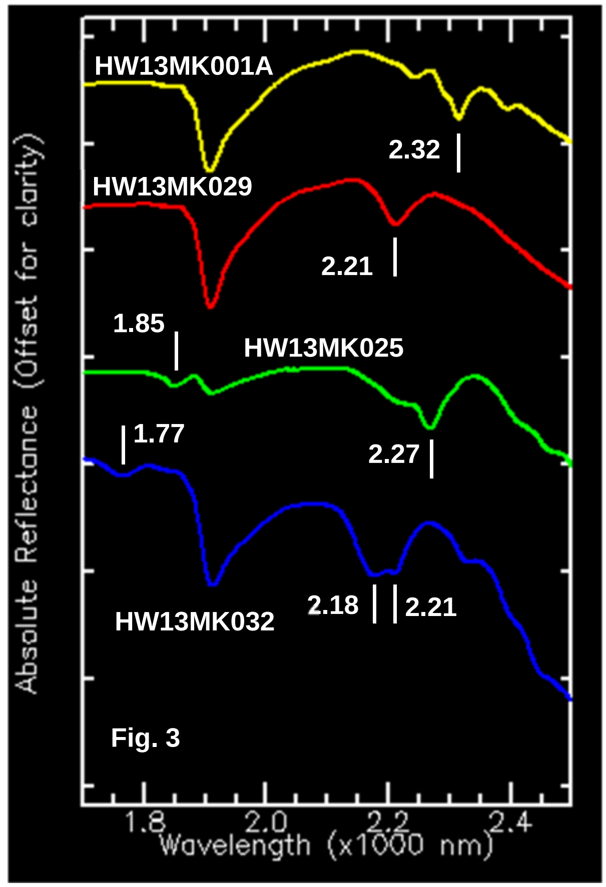
alunite and jarosite, respectively. Both minerals have been previously reported on Mauna Kea [e.g., 4,5]

The XRD patterns (not shown) also show the presence of clay minerals as indicated by the presence of the 001and 02ℓ peaks near 1.5 and 0.45 nm, respectively. Clay minerals are also indicated by the VNIR spectra (Figure 3; compare with spectra published by [5]) for the hematite ridge samples (Mg-OH = 2.32 µm; Al-OH = 2.21 µm). Spectral features for the alunite and jarosite, inferred by chemical evidence and assigned by XRD, are also present in the VNIR spectra (jarosite = 1.85 and 2.27 µm; alunite = 1.77 and 2.18 µm). The spectrum for HW13MK032 may also include a contribution from kaolinite (or halloysite) at 2.18 and 2.21 µm [5].





Discussion: Chemical and mineralogical data document the presence of a hematite-bearing ridge on Mauna Kea volcano. Clay minerals are associated with the hematite and also with sulfate-bearing phases (alunite and jarosite) located in strata proximate to the ridge. Sulfate-bearing phases were not detected on the hematite ridge itself. We tentatively suggest an acid-sulfate process where Fe^{2+} is leached from basaltic tephra (reducing conditions not required) and alunite is precipitated. Subsequent Fe^{2+} oxidation precipitates Fe^{3+} as either jarosite or hematite. Hematite is favored over jarosite under hydrothermal conditions (forced hydrolysis) [6]. The alunite fingerprint may not be as significant on Mars because the Al_2O_3, Na_2O, and K_2O contents of martian surface materials (e.g., ~10, ~2, and ~0.5 wt.%, respectively [7]) are less than the corresponding values for AUHT (Table 1).



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References: [1] Grotzinger *et al.* (2012) *Space Sci Rev*, *170*, 5. [2] Milliken *et al.* (2010) *GRL*, *37*, L04201. [3] Fraeman *et al.* (2013) *Geology*, *41*, 1103. [4] Morris *et al.* (2000) *JGR*, *105*, 1757. [5] Hamilton *et al.* (2008) *JGR*, *113*, E12S43. [6] Golden *et al.* (2008) *Am. Mineral.*, *93*, 1201. [7] Blake *et al.* (2013) *Science, 341*, 1239505.